Journal of Electrical Technology UMY (JET-UMY), Vol. 4, No. 1, June 2020
ISSN 2550-1186 e-ISSN 2580-6823

# Identifying Glucose Levels in Human Urine via Red Green Blue Color Compositions Analysis

Latifah Listyalina[1], Dhimas Arief Dharmawan[2], Evrita Lusiana Utari[*1]

[1]Department of Electrical Engineering, Faculty of Science and Technology, Universitas Respati Yogyakarta
Jalan Laksda Adisucipto Km 6.3, Sleman 55281, Telp (0274) 488781

[2]Department of Electrical Engineering, Faculty of Engineering, Universitas Muhammadiyah Yogyakarta
Jalan Brawijaya, Geblangan, Tamantirto, Kasihan, Bantul 55183, Telp (0274) 387656

*Corresponding author, e-mail: evrita_lusiana@yahoo.com

**Abstract** – *Diabetes mellitus (DM), a metabolic disorder caused by the lack of the insulin hormone, has become a health problem quite severe and is the most common endocrine disease. Recently, diagnosing diabetes could be carried out through monitoring the glucose level in human blood taken from the patient's finger or arm. On the other hand, a non-invasive blood sugar detector with a benedict test on human urine is an alternative to monitor blood sugar without injuring the body. The test output can be determined from the color of the color change of urine. However, manual evaluations on the urine color are prone to human subjectivity. In this paper, we present a computational method to automatically determine the blood sugar level based on the given urine color. The proposed method identified the blood sugar level by considering the color intensity on the red, green, and blue (RGB) channels of the urine color. In the experimental parts, the proposed method was capable of classifying the urine sample correctly. Hence, our approach can be beneficial for practical applications.*

***Keywords****: Color, Diabetes, Glucose, Identification, Urine*

## I. Introduction

Diabetes Mellitus (DM) or in Indonesia, better known as Sweet-smelling urine, has become a severe health problem, and one of the endocrine diseases most often found [1]. Diabetes Mellitus (DM) is a group of metabolic disorders with hyperglycemia characteristic occurring due to abnormal insulin secretion. It is a chronic disease that could carry off human life. Various epidemiological studies show an increasing trend in the incidence and prevalence of diabetes across the globe. According to the International Diabetes Federation (IDF), in 2013, 382 million people lived with diabetes. By 2035, the number is predicted to increase to 592 people. Of the 382 million people, 175 million of them have not been diagnosed. Thus, without any prevention, it may result in advanced complications.

Urine can be used as a sample to diagnose diabetes by involving copper sulfate or the so-called benedict solution. The reaction between this chemical solution and urine produces the color change. For example, the color change from bright blue to brick red indicates the high level of glucose in the urine, meaning that the person may suffer from DM. In general, the results can be classified into five classes namely negative (0% glucose), positive 1 (0.5-1% glucose), positive 2 (1-1.5% glucose), positive 3 (2-3.5% glucose), and positive 4 (> 3.5% glucose) [3].

In this paper, we proposed a new method to analyze the urine color change due to the benedict reaction. Our approach interprets the color of urine by considering the color intensity of each color band, namely the red, green, and blue channels. The color intensity of each band is regarded as the reading value of each sensor in the tool in [4]. The results of the experimental parts suggest that our method could identify the blood sugar level effectively. Hence, it is beneficial to use our method for broad applications of glucose level identification.

*Manuscript received April 2020, revised July 2020*

We organize the remaining sections of this paper as follows. In Section 2, we provide a theoretical basis for the proposed method. Section 3 describes the details of the proposed study. We present and discuss the experimental results in Section 4. Finally, Section 5 draws a concluding remark.

## II. Theoretical Basis

### II.1. Urinary System

The urinary system plays a vital role in excreting and eliminating the body's metabolic remains, and fluid and electrolyte balance. The urinary system consists of kidneys, ureter, bladder, and urethra. This system helps maintain homeostasis by producing urine, which is the result of metabolic waste [5].

Urine leaves both kidneys and passes through a pair of ureters and temporarily accommodated in the bladder. The urine excretion process, called micturition, occurs when there is a contraction on the muscles of the bladder. This contraction presses urine to come out through the urethra and out of the body, as shown in Fig. 1 [6].

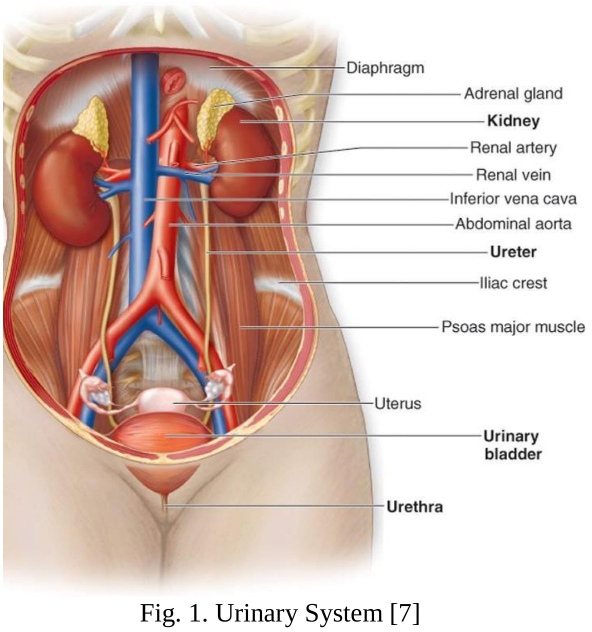



Fig. 1. Urinary System [7]

### II.2. Urine

Urine is a liquid waste product that has been filtered by the kidneys inside the human body. The urine characteristic is that it has a yellow color caused by the secretion of the pigment derived from blood. Hence, most urine color depends on the amount of liquid human drink. Artificial food coloring could also cause temporary changes in urine color. Drugs consumed by humans as a part of a particular disease therapy can also change the urine color [7].

The renal arteries carry urine originating from the blood that goes inside the kidney. The first step in the urine formation process is blood ultrafiltration performed in the glomerular capillaries. Subsequently, the process continues with the reabsorption of essential substances from the results of the filtration process. The reabsorption process happens in the human kidney. Finally, the essential substances are returned to the blood, while by the secretion process, the waste is removed from the human body through urines [8].

As depicted in Fig. 2, 95% of urine is water, while the remaining consist of dissolved substances such as nitrogenous wastes, hippuric acid, electrolytes, hormones, and various toxins or chemicals foreign [9]. Several examples of nitrogenous wastes include urea, uric acid, and creatinine. Meanwhile, electrolytes in urine consist of sodium, chlorine, potassium, ammonium, sulfate, phosphate ions, calcium, and magnesium. Urine specific gravity ranges from 1,001-1,035 depending on the urine concentration. In general, urine has a pH varies between 4.8-7.5, with an average of 6.0 [10].


Fig. 2. Urine Composition [11]

### II.3. Diabetes Mellitus

Diabetes mellitus (DM) is a metabolic disorder caused by a lack of the hormone insulin. The hormone insulin is produced by a group of beta cells in the pancreas gland and plays a vital role in metabolism glucose in body cells. According to the World Health Organization (WHO), the number of people with diabetes mellitus in Indonesia is around

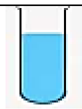
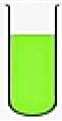
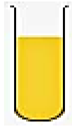
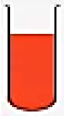
17 million people or 8.6% of the population. It ranks 4th after India, China, and the United States (US) (See Fig. 3 for the details). Based on the International Diabetes Federation (IDF) data, in 2014, about 9.1 million Indonesian people were diagnosed to live with DM. With these numbers, Indonesia ranked 5th globally, moving two positions up from its rank in 2013 [11][12].

### *II.4. Glucose Test*

In DM patients, most of the glucose in the blood is removed from the body through urine. Consequently, people with DM disorders suffer from several conditions, such as lack of energy, quickly tired, easily thirsty, and hungry, often tingling, frequent urination, and itching. Therefore, it is always beneficial to control the amount of glucose in the body.

Among the available approaches to determine the glucose level in human blood, urine tests are the most popular ones to determine sugar content in the urine, one of which is the benedict test [14]. In particular, a benedict test is beneficial to determine the presence of glycogen in the urine. During the test, benedict reagent with approximately 5 ml of a dose is taken and subsequently put in a test tube. Further, the benedict is mixed with about 5 to 8 drops of urine samples from people with diabetes. Finally, the test tube is placed in boiling water for 5 minutes, and the test tube is shaken until the color changes occur [15][16]. The color changes denote the sugar levels in the urine. Table I lists the urine color changes and the corresponding sugar levels.

TABLE I
THE CHANGES OF URINE COLOR IN BENEDICT TEST TOGETHER WITH THE CORRESPONDING SUGAR LEVELS

| No | Urine Color | Level |
|---|---|---|
| 1 |  | 0 |
| 2 |  | 1 |
| 3 |  | 2 |
| 4 |  | 3 |
| 5 |  | 4 |

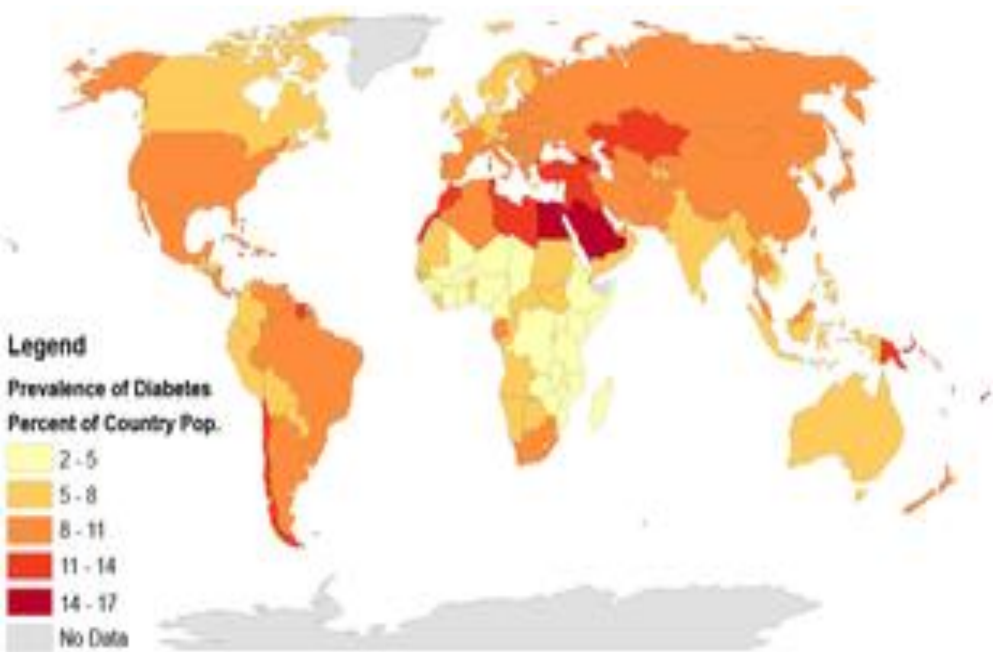


Fig. 3. The fact of Diabetes Mellitus [13]

An example of glucose test tools taking urine samples as the input was developed by [4]. The tool in [4] uses three TCS3200 sensors to capture the color change, where each of the sensors corresponds to the reading value of the red, green, and blue bands. Table 2 lists the reading values by the tool on different color spectrums.

### *II.5. Digital Images*

From the mathematical point of view, an image is a continuous function of the light intensity in a two-dimensional plane. The image can also be interpreted as a collection of pixels arranged in a two-dimensional array. Each pixel of an image has a particular range value defining a measure of light intensity at that point [17]. In general, for color and grayscale images, the pixel value ranges from 0 to 255. Fig. 4 shows a color image and its respective grayscale map.

As shown in Fig. 4, a digital image can be represented in the form of a matrix H × W, where H and W denote the height and width of the image, respectively [18]. The origin point of the image coordinate system is located in the upper left-hand corner, while that of the cartesian coordinate system is located in the lower-left corner [19].

TABLE II

READING OUTPUTS BY THE TOOL IN [4] ON DIFFERENT COLOR SPECTRUMS

| LV | Color | Red Sensor | Green Sensor | Blue Sensor |
|---|---|---|---|---|
| | | 1535 | 1065 | 799 |
| 0 | Clear Blue | 4997 | 2083 | 1618 |
| | | 4465 | 2008 | 1481 |
| | | 2969 | 2668 | 4016 |
| 1 | Yellowish Green | 1195 | 945 | 1321 |
| | | 2977 | 2662 | 4018 |
| | | 1833 | 2614 | 4437 |
| 2 | Murky Yellow | 582 | 736 | 1242 |
| | | 1663 | 2681 | 4619 |
| | | 1073 | 2626 | 2846 |
| 3 | Orange Mud | 745 | 1279 | 1565 |
| | | 815 | 2515 | 2669 |
| | | 1528 | 4414 | 4129 |
| 4 | Brick red | 3111 | 4700 | 4090 |
| | | 3836 | 5112 | 4629 |

(a)

(b)

Fig. 4. (a) A color image and (b) its respective grayscale map

In general, a color image, shown in Fig. 4 (a), consists of three bands, namely the red, green, and blue channels [20]. The color compositions of a color image can be illustrated using a color diagram, as shown in Fig. 5.

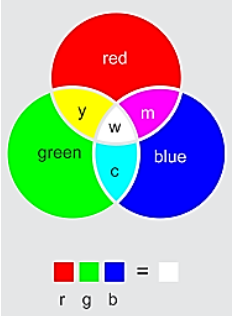



Fig. 5. The RGB color composition of a color image

## III. Proposed Method

As mentioned earlier, this study aims to develop a new method to analyze the color change in the urine automatically. The change in urine color was obtained by mixing the human urine samples with benedict reagents in a test tube. Then, the mixture was heated to the maximum temperature of 1000 °C and gently shaken. We subsequently used the tool in [4] to read the color intensity of the urine.

Based on the reading values of the sensors in Table 2, we developed new rules as follows:

1. Negative (LV 0), if the reading value of the red sensor is the largest, compared to those of the green and blue sensors:
$$\text{LV}\,0: R = \max(R, G, B). \quad (1)$$
2. Positive 1 (LV 1), if the reading value of the blue sensor is larger than that of the red sensor, and that of the red sensor is larger than that of the green sensor:
$$\text{LV}\,1: B > R > G. \quad (2)$$
3. Positive 2 (LV 2), if the reading value of the blue sensor is larger than that of the green sensor, and that of the green sensor is larger than that of the red sensor. Moreover, the different of the reading values by the green and blue sensors are larger than 300:
$$\text{LV}\,2: \begin{matrix} B > G > R, \\ G - B > 300. \end{matrix} \quad (3)$$
4. Positive 3 (LV 3), if the reading value of the blue sensor is larger than that of the green sensor, and that of the green sensor is larger than that of the red sensor. Moreover, the different reading values by the green and blue sensors are equal to or less than 300:
$$\text{LV}\,3: \begin{matrix} B > G > R, \\ G - B \le 300. \end{matrix} \quad (4)$$
5. Positive 4 (LV 4), if the reading value of the green sensor is the largest between the blue and red sensors:
$$\text{LV}\,4: G = \max(R, G, B). \quad (5)$$

## IV. Results and Discussion

In this section, we demonstrate the efficacy of our algorithm in identifying the color changes in human urine samples. Before being used to identify the color changes in urine samples, we initially tested the tool in [4] to read color in several synthetic data. This phase is essential to ensure that all the sensors in the tool by [4] provide desirable reading values.

The investigation of RGB values patterns became a reference to determine the urine glucose levels. The identification results of all samples are presented in Table 3. This table also includes the corresponding readings from the clinical lab as the ground truth. The table implies that the tool failed to provide correct results on two samples.

TABLE III
THE IDENTIFICATION RESULTS ON ALL SAMPLES TOGETHER WITH THE CORRESPONDING READINGS FROM THE CLINICAL LAB AS THE GROUNDTRUTH

| No | Red Sensor | Green Sensor | Blue Sensor | Our Result | Groundtruth | Remark |
|---|---|---|---|---|---|---|
| 1 | 1540 | 1065 | 805 | LV 0 | LV 0 | Correct |
| 2 | 672 | 1269 | 1560 | LV 3 | LV 3 | Correct |
| 3 | 2977 | 2662 | 4018 | LV 1 | LV 1 | Correct |
| 4 | 744 | 1279 | 1566 | LV 3 | LV 3 | Correct |
| 5 | 5003 | 2076 | 1615 | LV 0 | LV 0 | Correct |
| 6 | 1199 | 946 | 1322 | LV 1 | LV 1 | Correct |
| 7 | 881 | 1327 | 2006 | LV 2 | LV 2 | Correct |
| 8 | 1019 | 1761 | 2698 | LV 2 | LV 2 | Correct |
| 9 | 5000 | 2082 | 1617 | LV 0 | LV 0 | Correct |
| 10 | 2970 | 2669 | 4026 | LV 1 | LV 1 | Correct |
| 11 | 4986 | 2072 | 1608 | LV 0 | LV 0 | Correct |
| 12 | 1200 | 945 | 1322 | LV 1 | LV 1 | Correct |

The Table 3 shows that our method could provide correct identification of most urine samples. It indicates that this method is useful for glucose level identification.

## V. Conclusion

In this paper, we have presented a computational method to automatically determine the blood sugar level based on the urine color samples. The proposed method identifies the blood sugar level by considering the color intensity on the red, green, and blue (RGB) channels of the urine color. In the experimental parts, the proposed method was capable of classifying the urine sample correctly. Hence, our approach is beneficial for broad applications of glucose level identification.

## References

[1] Ramadhan, M. (2017). Faktor Yang Berhubungan Dengan Kejadian Diabetes Mellitus Di Rsup Dr Wahidin Sudirohusodo Dan Rs UniversitasHasanuddin Makassar. Fakultas Kesehatan Masyarakat Universitas Hasanuddin Makasar.

[2] IDF. (2013). IDF Diabetes Atlas Sixth Edition, International Diabetes Federation 2014. http://www.idf.org/sites/default/files/EN 6E Atlas Full 0.pdf.

[3] Putra, G et all. (2015). Rancang Bangun Alat Ukur Kadar Gula Darah NonInvasive Berbasis Mikrokontroler Atmega 328P Dengan Mengukur Tingkat Kekeruhan Spesimen Urine Menggunakan Paket Sensor Photodiode Dan Light Emiting Diode. Jurusan Teknik Elekto Universitas Mataram

[4] Foju, Yohanes Yuvenalis. (2019). Perancangan Alat Pendeteksi Gula Darah Non-Invasive Dengan Uji Benedict Menggunakan Sensor Tcs3200. Yogyakarta: Universitas respati Yogyakarta.

[5] Halis, I. (2017). Rancangan Bangun Sistem Informasi Kondisi Dehidrasi Tumbuh Melalui Warna Urin (Smart Toilet). Fakultas Sains Dan Teknologi Universitas Islam Negeri Maulana Malik Ibrahim Malang.

[6] Prabowo dan Pranata. (2014). Buku Ajar Asuhan Keperawatan Sistem Perkemihan (edisi ke 1). Yogyakarta: Nuha Medika.

[7] Almatsier, S. (2019). Prinsip Dasar Ilmu Gizi. Jakarta: Gramedia Pustaka Indonesia.

[8] Syaifuddin. (2007). Fisiologi Tubuh Manusia Untuk Mahasiswa Keperawatan Edisi 2. Jakarta: Salemba Medika.

[9] Purnomo, B. B. (2014). Dasar-dasar urologi. Edisi Ketiga. Malang: Penerbit CV Sagung Seto.

[10] Hapsari, M. Penggalih & E. Huriyati. (2007). Gaya Hidup, Status Gizi dan Stamina Atlet Pada Sebuah Klup Sepak Bola. Berita Kedokteran Masyarakat, hal. 192-199.

[11] Hapsari, M. Penggalih & E. Huriyati. (2007). Gaya Hidup, Status Gizi dan Stamina Atlet Pada Sebuah Klup Sepak Bola. Berita Kedokteran Masyarakat, hal. 192-199.

[12] Bagian Patologi Klinik. (2018). Buku Panduan Kerja Keterampilan Pemeriksaan Glukosa Urin. Fakultas Kedokteran Universitas Hasanuddin. Makassar.

[13] Cahyati SM. (2015). Hubungan Tingkat Pengetahuan Diet Diabetes Mellitus Dengan Kepatuhan Diet Pada Penderita Diabetes Mellitus Tipe Ii Di Dusun Karang Tengah Yogyakarta. Yogyakarta: Sekolah Tinggi Ilmu Kesehatan Aisyiyah.

[14] Cosmo. (2014). Kenali 3 Jenis Dehidrasi. Diakses pada tanggal 04 september 2017 dari http://www.cosmopolitan.co.id/article/read/5/2014/4220/kenali-3-jenis-dehidrasi.

[15] Meeto, D dan Allen, G. (2010). Understanding diabetes melitus and its management: an overview. https://www.juronghealthcampus.com.

[16] Pertiwi, D. (2015). Status Dehidrasi Jangka Pendek Berdasarkan Hasil Pengukuran Puri ( Periksa Urin Sendiri) Menggunakan Grafik Warna Urin Pada Remaja Kelas 1 Dan 2 Di Sman 63 Jakarta Tahun 2015. Fakultas Kedokteran Dan Ilmu Kesehatan Universitas Islam Negeri Syarif Hidayatullah. Jakarta.

[17] Low, A. (1991). *Introduction Computer Vision and Image Processing*, Mc Graw Hill Book Company, London.

[18] Dharmawan, D.A., Listyalina, L. (2018). Implementation of GLCM for Features Extraction and Selection of Batik Images. *Journal of Electrical Technology UMY (JET-UMY)*, *2*(1), 7-11.

[19] Mabrur, S. Si, Andik. (2011). Pengolahan Citra Digital Menggunakan Matlab. Tulungagung.

[20] Listyalina, L., Dharmawan, D.A. (2019). Detection of Optic Disc Centre Point in Retinal Image. *Journal of Electrical Technology UMY (JET-UMY), Vol. 3*(1), 19-23.

## Authors' information

**Latifah Listyalina** is a lecturer at the Department of Electrical Engineering, Faculty of Science and Technology, Universitas Respati Yogyakarta. She received the B.Eng. degree in Biomedical Engineering from Universitas Airlangga, Indonesia, in 2013 and the M.Eng. degree in Electrical Engineering from Universitas Gadjah Mada, Indonesia, in 2016. Her research interests include biomedical signal and image processing, computer vision, and pattern recognition.

**Dhimas Arief Dharmawan** is a lecturer at the Department of Electrical Engineering, Faculty of Engineering, Universitas Muhammadiyah Yogyakarta. He received the B.Eng. degree in Electrical Engineering from Universitas Gadjah Mada, Yogyakarta, Indonesia in 2014. He is currently pursuing a Ph.D. degree in Electrical Engineering at Nanyang Technological University (NTU), Singapore. His research interests include image filtering and segmentation, machine learning, computer vision, and pattern recognition.

**Evrita Lusiana Utari** is a lecturer at the Department of Electrical Engineering, Faculty of Science and Technology, Universitas Respati Yogyakarta. She received the B.Eng. degree in Electrical Engineering, IST Akprind, and the M.Eng. degree in Electrical Engineering from Universitas Gadjah Mada, Indonesia. Her research interests include biomedical signal and image processing and instrumentation.